

# SPECIFICATION

Electronic Version 1.2.8

Stylesheet Version 1.0

## **METHOD AND SYSTEM FOR AUTOMATICALLY EXTENDING A TIRE PRESSURE MONITORING SYSTEM FOR AN AUTOMOTIVE VEHICLE TO INCLUDE AUXILIARY TIRES**

### **Cross Reference to Related Applications**

The present invention is related to applications (Attorney Docket 201-1003) entitled "Method And System For Mitigating False Alarms In A Tire Pressure Monitoring System For An Automotive Vehicle" (Attorney Docket 201-0718) entitled "Method And System For Resetting Tire Pressure Monitoring System For An Automotive Vehicle" (Attorney Docket 201-0745) entitled "Method And System For Detecting The Presence Of A Spare Replacement In A Tire Pressure Monitoring System For An Automotive Vehicle" (Attorney Docket 201-0738) entitled "Method And System Of Notifying Of Overuse Of A Mini-Spare Tire In A Tire Pressure Monitoring System For An Automotive Vehicle" (Attorney Docket 201-1266) entitled "Method And Apparatus For Identifying The Location Of Pressure Sensors In A Tire Pressure Monitoring System" (Attorney Docket 201-1265) entitled "Tire Pressure Monitoring System With A Signal Initiator" (Attorney Docket 201-1389) entitled "Method And Apparatus For Automatically Identifying The Location Of Pressure Sensors In A Tire Pressure Monitoring System"; (Attorney Docket 201-1424) entitled "Method And Apparatus For Reminding The Vehicle Operator To Refill The Spare Tire In A Tire Pressure Monitoring System" filed simultaneously herewith and incorporated by reference herein.

### **Background of Invention**

- [0001] The present invention relates generally to a system for monitoring tire pressure in an automotive vehicle, and more particularly, to a method and system for automatically including auxiliary tires such as for trailers and additional spare tires.
- [0002] Various types of pressure sensing systems for monitoring the pressure within the tires of an automotive vehicle have been proposed. Such systems generate a pressure signal using an electromagnetic (EM) signal, which is transmitted to a receiver. The pressure signal corresponds to the pressure within the tire. When the tire pressure drops below a predetermined pressure, an indicator is used to signal the vehicle operator of the low pressure.
- [0003] Various tire manufacturers have suggested various locations for the pressure sensors. Known systems include coupling a pressure sensor to the valve stem of the tire. Other known systems and proposed systems locate the pressure sensors in various locations within the tire wall or tread.
- [0004] Sport utility vehicles and other large vehicles are often used to pull a trailer. It is desirable to monitor the condition of the trailer tires as well as the primary vehicle tires. U.S. Patent 6,225,895 describes a system in which the condition tires to a trailer are monitored using a mechanical linkage therebetween. The system visually monitors the conditions of the tires and does not directly measure pressure loss.
- [0005] U.S. Patent 5,061,917 measures various parameters and transmits them to the cab of the tractor trailer unit. The transmitter to this system only transmits when a fault occurs. Also, a bank of switches is used to provide the position of each tire on the vehicle before operating.
- [0006] One problem with the above systems is that driver intervention is required to properly configure the system. Another drawback is that sensors from adjacent vehicles may also be read as belonging to the vehicle monitoring system.
- [0007] Also, the trailer or the top of the vehicle may also be used to store additional spare tires when more than one spare tire is desirable. Such conditions such as an off-road condition far from most civilization require having more than one spare. Additional spare tires are typically not provided for in tire monitoring systems. It would therefore be desirable to provide a system in which spare tires and trailer tires

are monitored.

## Summary of Invention

[0008] The present invention provides a system and method for automatically monitoring auxiliary tire including additional spares and trailer tires.

[0009] In one aspect of the invention, a tire pressure monitoring system for a vehicle includes a speed sensor generating a speed signal indicative of vehicle speed, a timer generating a time signal, a warning status memory having warning statuses therein. The system further includes a plurality of rolling tires in respective rolling location. The plurality of rolling tires and respective rolling transmitters. An auxiliary tire in an auxiliary location has an auxiliary transmitter that generates an auxiliary sensor transmission signal. A controller is coupled to the rolling transmitters, the spare tire transmitter and the warning status memory 26. The controller receives the auxiliary sensor transmission signal. When the speed is greater than a predetermined speed and, when the time signal is greater than a predetermined time, the controller associates the auxiliary sensor identification to an auxiliary location of the warning status memory.

[0010] In a further aspect of the invention, a method for operating a tire pressure monitoring system having an auxiliary tire in an auxiliary location and a warning status memory comprises: generating a speed signal corresponding to a vehicle speed; receiving an auxiliary sensor transmitter identification signal; generating a cumulative time signal corresponding to a cumulative receiving time of the transmitter identification signal; when the speed is greater than a predetermined speed and when the cumulative time signal is greater than a predetermined time, associating the auxiliary sensor identification to an auxiliary location of the warning status memory.

[0011] One advantage of the invention is that inadvertent activation due to adjacent vehicles transmitting is avoided. Likewise, driver intervention is also not required to recognize the additional pressure transmitters.

[0012] Other advantages and features of the present invention will become apparent when viewed in light of the detailed description of the preferred embodiment when taken in conjunction with the attached drawings and appended claims.

## Brief Description of Drawings

- [0013] Figure 1 is a block diagrammatic view of a pressure monitoring system according to the present invention.
- [0014] Figure 2 is a functional flowchart of the monitoring system according to the present invention.
- [0015] Figure 3 is a block diagrammatic view of a pressure transmitter according to the present invention.
- [0016] Figure 4 is a diagrammatic view of a digital word from a pressure transmitter.
- [0017] Figure 5 is a flow chart illustrating determining a pressure status in a first stage of pressure determination according to the present invention.
- [0018] Figure 6 is a flow chart illustrating determining a warning status in a second stage of pressure determination according to the present invention.
- [0019] Figure 7 is a state diagram of low pressure sensor status according to the present invention.
- [0020] Figure 8 is a state diagram of high pressure sensor status according to the present invention.
- [0021] Figure 9 is a state diagram of a flat pressure sensor status.
- [0022] Figure 11 is a state diagram of a low pressure warning status.
- [0023] Figure 12 is a state diagram of a high pressure warning status.
- [0024] Figure 13 is a state diagram of a flat pressure warning status.
- [0025] Figure 14 is a flowchart of the operation of the system when a tire pressure is increased by filling.
- [0026] Figure 15 is a flowchart of the operation of the system when a spare tire is placed into the rolling position.
- [0027] Figure 16 is a state diagram of the spare tire identification according to the

present invention.

- [0028] Figure 17 is a block diagrammatic view of a trailer having pressure circuits according to the present invention.
- [0029] Figure 18 is an elevational view of a display according to the present invention.
- [0030] Figure 19 is a flow chart of a method of automatically updating the tire pressure monitoring system in the presence of additional tires.

## Detailed Description

- [0031] In the following figures, the same reference numerals will be used to illustrate the same components. Those skilled in the art will recognize that the various components set forth herein could be changed without varying from the scope of the invention.
- [0032] Referring now to Figure 1, an automotive vehicle 10 has a pressure monitoring system 12 for monitoring the air pressure within a left front tire 14a, a right front tire 14b, a right rear tire 14c, and a left rear tire 14d. Each tire 14a-14d has a respective tire pressure sensor circuit 16a, 16b, 16c, and 16d, each of which has a respective antenna 18a, 18b, 18c, and 18d. Each tire is positioned upon a corresponding wheel.
- [0033] A fifth tire or spare tire 14e is also illustrated having a tire pressure sensor circuit 16e and a respective antenna 18e. Although five wheels are illustrated, the pressure of various numbers of wheels may be increased. For example, the present invention applies equally to vehicles such as pickup trucks that have dual wheels for each rear wheel. Also, various numbers of wheels may be used in a heavy duty truck application having dual wheels at a number of locations. Further, the present invention is also applicable to trailers and extra spares as will be further described below.
- [0034] Each tire 14 may have a respective initiator 20a-20e positioned within the wheel wells adjacent to the tire 14. Initiator 20 generates a low frequency RF signal initiator and is used to initiate a response from each wheel so that the position of each wheel may be recognized automatically by the pressure monitoring system 12. Initiators 20a-20e are preferably coupled directly to a controller 22. In commercial embodiments where the position programming is done manually, the initiators may be eliminated.

- [0035] Controller 22 is preferably a microprocessor based controller having a programmable CPU that may be programmed to perform various functions and processes including those set forth herein.
- [0036] Controller 22 has a memory 26 associated therewith. Memory 26 may be various types of memory including ROM or RAM. Memory 26 is illustrated as a separate component. However, those skilled in the art will recognize controller 22 may have memory 26 therein. Memory 26 is used to store various thresholds, calibrations, tire characteristics, wheel characteristics, serial numbers, conversion factors, temperature probes, spare tire operating parameters, and other values needed in the calculation, calibration and operation of the pressure monitoring system 12. For example, memory may contain a table that includes the sensor identification thereof. Also, the warning statuses of each of the tires may also be stored within the table.
- [0037] Controller 22 is also coupled to a receiver 28. Although receiver 28 is illustrated as a separate component, receiver 28 may also be included within controller 22. Receiver 28 has an antenna 30 associated therewith. Receiver 30 is used to receive pressure and various information from tire pressure circuits 16a-16e. Controller 22 is also coupled to a plurality of sensors. Such sensors may include a barometric pressure sensor 32, an ambient temperature sensor 34, a distance sensor 36, a speed sensor 38, a brake pedal sensor 40, and an ignition sensor 42. Of course, various other types of sensors may be used. Barometric pressure sensor 32 generates a barometric pressure signal corresponding to the ambient barometric pressure. The barometric pressure may be measured directly, calculated, or inferred from various sensor outputs. The barometric pressure compensation is preferably used but is not required in calculation for determining the pressure within each tire 14. Temperature sensor 34 generates an ambient temperature signal corresponding to the ambient temperature and may be used to generate a temperature profile.
- [0038] Distance sensor 36 may be one of a variety of sensors or combinations of sensors to determine the distance traveled for the automotive vehicle. The distance traveled may merely be obtained from another vehicle system either directly or by monitoring the velocity together with a timer 44 to obtain a rough idea of distance traveled. Speed sensor 38 may be a variety of speed sensing sources commonly used in

automotive vehicles such as a two wheel used in anti-lock braking systems, or a transmission sensor.

- [0039] Timer 44 may also be used to measure various times associated with the process set forth herein. The timer 44, for example, may measure the time the spare tire is stowed, or measure a time after an initiator signal.
- [0040] Brake pedal sensor 41 may generate a brake-on or brake-off signal indicating that the brake pedal is being depressed or not depressed, respectively. Brake pedal sensor 41 may be useful in various applications such as the programming or calibrating of the pressure monitoring system 12.
- [0041] Ignition sensor 42 may be one of a variety of types of sensors to determine if the ignition is powered on. When the ignition is on, a run signal may be generated. When the ignition is off, an off signal is generated. A simple ignition switch may act as an ignition sensor 42. Of course, sensing the voltage on a particular control line may also provide an indication of whether the ignition is activated. Preferably, pressure monitoring system 12 may not be powered when the ignition is off. However, in one constructed embodiment, the system receives information about once an hour after the ignition has been turned off.
- [0042] A telemetric system 46 may be used to communicate various information to and from a central location from a vehicle. For example, the control location may keep track of service intervals and use and inform the vehicle operator service is required.
- [0043] A counter 48 may also be included in control system 12. Counter 48 may count, for example, the number of times a particular action is performed. For example, counter 48 may be used to count the number of key-off to key-on transitions. Of course, the counting function may be inherent in controller 22.
- [0044] Controller 22 may also be coupled to a button 50 or plurality of buttons 50 for inputting various information, resetting the controller 22, or various other functions as will be evident to those skilled in the art through the following description.
- [0045] Controller 22 may also be coupled to an indicator 52. Indicator 52 may include an indicator light or display panel 54, which generates a visual signal, or an audible

device 56 such as a speaker or buzzer that generates an audible signal. Indicator 52 may provide some indication as to the operability of the system such as confirming receipt of a signal such as a calibration signal or other commands, warnings, and controls as will be further described below. Indicator may be an LED or LCD panel used to provide commands to the vehicle operator when manual calibrations are performed.

[0046] Referring now to Figure 2, a pressure monitoring system 12 having various functional blocks is illustrated. These functional blocks may take place within receiver 28, controller 22, or a combination thereof. Also, memory 26 is used to store the various ranges. An end-of-line (EOL) tester 58 may also be coupled to pressure monitoring system. EOL tester 58 provides test functions to EOL diagnostic block 60. EOL tester 58 in conjunction with EOL diagnostic block 60 may be used to provide acceptable pressure ranges 62 and other diagnostic functions to determine fault within the system. The EOL tester 58 may be used in the manufacturing process to store various information in the memory such as various thresholds, tire characteristics, and to initially program the locations corresponding to the vehicle tires.

[0047] Vehicle speed sensor 38, ignition switch 42, and brake on/off switch 41 may be coupled to a manual learn mode activation input process block 64. Together block 64 and sensors 38, 41, and 42 allow an association block 66 to associate the various tire pressure sensors to the locations of the vehicles. Block 66 associates the various tire pressure sensors in the memory at block 68. The transmissions from the various sensors are decoded in block 70, which may be performed in receiver 28 above. The decoded information is provided to block 66 and to a block 72, which processes the various information such as the ranges, the various sensor locations, and the current transmission process. In the processing frame the sensor status pressure and transmission ID may be linked to a tire pressure monitor 74 which may be used to provide a warning status to an output block 76 which in turn may provide information to an external controller 78 and to indicator 52.

[0048] An auto learn block 80 may also be used to associate the various tire pressure sensor monitors with the locations of the tires in the vehicle. This process may replace



or be in addition to the manual learn block 64. The auto learn function, however, uses initiators such as the initiator 20b as shown. The various features of Figure 2 will be described further in more detail.

- [0049] Referring now to Figure 3, a typical tire pressure sensor circuit 16a is illustrated. Although only one tire pressure sensor circuit 16 is shown, each may be commonly configured. Pressure monitoring system 12 has a transmitter/receiver or transceiver 90. Transmitter/receiver 90 is coupled to antenna 18a for transmitting various information to receiver 28. The receiver portion may be used to receive an activation signal for an initiator located at each wheel. The pressure sensor may have various information such as a serial number memory 92, a pressure sensor 94 for determining the pressure within the tire, a temperature sensor 96 for determining the temperature within the tire, and a motion detector 98 which may be used to activate the system pressure sensing system. The initial message is referred to as a "wake" message, meaning the pressure sensing circuit is now activated to send its pressure transmissions and the other data.
- [0050] Each of the transceiver 90, serial number memory 92, pressure sensor 94, temperature sensor 96, and motion sensor 98 coupled to battery 100. Battery 100 is preferably a long-life battery capable of lasting through the life of the tire.
- [0051] A sensor function monitor 101 may also be incorporated into tire pressure sensor circuit 16. Sensor function monitor 101 generates an error signal when various portions of the tire pressure circuit are not operating or are operating incorrectly. Also, sensor function monitor may generate a signal indicating that the circuit 16 is operating normally.
- [0052] Referring now also to Figure 4, a word 102 generated by the tire pressure sensor circuit 16 of Figure 3 is illustrated. Word 102 may comprise a transmitter identification serial number portion 104 followed by a data portion 106 in a predetermined format. For example, data section 106 may include a wake or initial status pressure information followed by temperature information. Motion detector 28 may initiate the transmission of the word 102 to the transmitter/receiver 90. The word 102 is preferably such that the decode RF transmission block 70 is able to decode the information and validate the word while providing the identification

number or serial number, the pressure, the temperature, and a sensor function.

[0053] Referring now to Figure 5, a high level flow chart illustrating obtaining a sensor pressure status from the measured pressure is illustrated. The pressure status is determined in a similar manner for each of the tires on the vehicle. In block 120 the pressure is measured at the pressure sensor and transmitted to the receiver and is ultimately used in the controller. The pressure measured is compared to a low pressure threshold and a low pressure warning is generated if the measured pressure is below the low pressure threshold. In block 124 if the measured pressure is above the high pressure warning, then a high pressure warning is generated. In block 126 if the measured pressure is below a flat pressure, then a flat pressure warning is generated. In block 128 the pressure status is obtained from blocks 122, 124, and 126. The sensor pressure status is a first stage of pressure monitoring according to the present invention.

[0054] Referring now to Figure 6, a second stage of pressure monitoring is illustrated in a high level flow chart view. Once the sensor pressure status is obtained in block 128 of Figure 5, a low pressure warning status, a high pressure warning status, a flat pressure warning status, and an overall sensor status is used to form a composite warning status. In block 130 the low pressure warning status is determined. In block 132 the high pressure warning status is determined. In block 134 a flat pressure warning status is determined. As will be further described below, preferably several measurements take place during normal operation to confirm the status. Each of the low pressure warning status, high pressure warning status, and flat pressure warning status are combined together to form the composite warning status in block 136. The low pressure warning status, the high pressure warning status, and the flat pressure warning status may have two statuses indicative of a warning state indicating the conditions are not met and a not warning state indicating the conditions are not met.

[0055] Referring now to Figure 7, a state diagram for determining the sensor pressure status is illustrated. Block 138 corresponds to a not low sensor status. In the following example, both the front tire pressure and the rear tire pressure may have different threshold values. Also, the spare tire may also have its own threshold values. When any of the tires is below its low pressure threshold and a warning status is not low,

block 140 is performed. Of course, those in the art will recognize that some hysteresis may be built into the system so that not exactly the same thresholds may be used to transition back. In block 140 the low warning status is determined in the second stage as will be described below. In block 140 when the warning status is not low and the sensor is equal to or above the threshold for the tire, then the sensor pressure status is not low and the system returns to block 138. In block 140 when a low warning status is determined, then block 142 is performed. In block 142 when the pressure is greater than or equal to the threshold pressure of the associated tire, then block 144 is performed. In block 144 a "not low" warning status is determined as will be further described below. When the tire pressures are less than their associated low thresholds, then block 142 is executed. In block 144 when a warning status of not low is determined, block 138 is executed. Blocks 138 through 144 illustrate a continuous loop in which the sensor readings are monitored and a sensor pressure status and warning status are used to move therethrough.

[0056] Referring now to Figure 8, a similar state diagram to that of Figure 7 is illustrated relative to a high pressure threshold. In block 146 the warning status is not high. To move from block 146 to 148 the pressure of the particular tire exceeds a high pressure threshold. When the pressure reading exceeds one of the high pressure thresholds for one of the tires, block 148 determines a high warning status. A high warning status is determined as will be further described below. When subsequent readings of the pressure sensor are lower than or equal to the high pressure threshold, then block 146 is again executed. In block 148 if the high warning status criteria are met, a high warning status is generated and block 150 is executed. Again, the thresholds may be offset slightly to provide hysteresis. In block 150 when the pressure reading drops below a high pressure threshold then block 144 is executed. If subsequent readings are greater than the high pressure threshold then block 150 is again executed. In block 152 when the not high warning status criteria are met, as will be further described below, a not high warning status is generated and block 146 is again executed.

[0057] Referring now to Figure 9, a state diagram for determining the presence of a flat tire is illustrated. When the warning status is not flat and the tire pressure for each tire falls below a predetermined flat threshold, then block 156 is executed. Again, the

thresholds may be offset slightly to provide hysteresis. In block 56 if a subsequent pressure reading is greater than the flat threshold, then block 154 is again executed. In block 156, if the criteria for generating a flat warning status is met, as will be further described below, block 158 is executed. In block 158 when the pressure reading of a subsequent reading exceeds or is equal to a flat threshold, then block 160 is executed. Block 160 determines a not flat warning status in a similar manner to that of block 156. In block 160 if the subsequent readings drop below the flat warning threshold, then block 158 is again executed. In block 160 if the criteria for not flat warning status is met, then block 154 is executed.

[0058] Preferably, the processes shown in Figures 7, 8, and 9 are simultaneously performed for each wheel.

[0059] Referring now to Figure 10, the results obtained from Figures 7, 8, and 9 are shown in respective columns. True in the columns refers to that pressure threshold being crossed. Thus, the output pressure status shown in the right hand column is "in range" when each of the pressure thresholds are not met. A flat pressure status refers to the flat pressure threshold being met. A low pressure status is obtained when a low pressure threshold is crossed, and a high pressure status when a high pressure threshold is exceeded.

[0060] Referring now to Figure 11, blocks 140 and 144 of Figure 7 are illustrated in further detail. In each of these blocks the qualification process for either a pressure not low warning status or a low pressure warning status is illustrated. Upon an initial status reading the system is set to a false low warning status as indicated by arrow 163 and block 162 is executed. On the initial status reading, if a low pressure status is obtained in the first reading, block 164 is executed which immediately generates a low warning status. Thus, no waiting periods or other measurements are necessary from an initial standpoint. Loop 165 back to the pressure not low block 162 signifies that the initial value was in range and the status value is not an initial value. When the pressure status signal is low from Figure 7, a warning qualification process is started in block 168. In block 168 if subsequent pressure status signals are not low, block 162 is executed. In block 168 if a predetermined number of pressure status signals are low or a certain number of pressure status signals over a fixed time period are

low, for example five warning events, block 164 is executed. In block 164 when a not low pressure status is obtained a qualification timer is initiated in block 170. If a subsequent low pressure warning is received, then block 164 is again executed. In block 170 if a low warning qualification timer expires, the low warning status is false or "not low pressure" and block 162 is executed. The warning status is initiated as represented by arrow 163 by a wake message received from a spare and the vehicle speed is greater than three miles per hour and the low warning status indicates the tire pressure is not low.

[0061] Referring now to Figure 12, a state diagram of the qualification for generating a warning status for high pressure is illustrated. Once again, an initial step represented by arrow 177 is a default state in which the initial status is set to not high. In block 178 when the pressure sensor status is high, block 180 is executed in which the high pressure is qualified. In the transition from block 178 to 180 a high warning qualification process is initiated. As mentioned above in Figure 11, the qualification may be a predetermined number of sequential pressure sensor status readings being high or a predetermined number of pressure sensor status readings being high over a predetermined time. In block 180 if a pressure status is not high before qualification, step 178 is re-executed. In block 180 if a predetermined number of pressure sensor status readings are high, then a high warning status is generated in block 182. When a high warning status is generated, if a subsequent pressure status is not high then a qualification timer again starts in block 184. In block 184 if a subsequent pressure status is high then step 182 is executed. In step 184 the not high pressure is qualified before issuing a not high warning status. Thus, a predetermined number of not high pressure statuses must be received before qualification. When a predetermined number of not high pressures are obtained, step 178 is again executed.

[0062] Referring now to Figure 13, a flat warning status is generated in a similar manner to the low warning status of Figure 11. The difference between flat warning and low warning is the flat warning is a substantially lower pressure than the low warning. This system also begins when a wake up message is received and the speed is greater than three miles per hour. Other considerations may also initiate the process. The default is illustrated by arrow 191. When the first pressure status reading is obtained and the pressure sensor status indicates a flat tire, a flat warning status of true is provided in

block 194. Loop 196 resets the initial value flag to false after the initial status value is received. In block 192 if a subsequent sensor pressure status is flat, a qualification timer is initiated in block 198. In block 198 if a not flat sensor pressure status is received, block 192 is again executed. In block 198 if the qualification process has a predetermined number of flat warning events, either consecutively or during a time period, block 194 is executed. In block 194 if a not flat sensor pressure status is obtained a not flat pressure qualification process is initiated in block 200. In block 200 if a subsequent flat warning is received, block 194 is again executed. In block 200 if a predetermined number of not flat pressure statuses are provided, the flat warning status is not false, then block 192 is again executed.

- [0063] As mentioned above in Figure 6, the output of the warning status generators of Figures 11, 12, and 13 generate a composite warning status as illustrated by the following table.
- [t1]

Sensor Status	Flat Warning Status	Low Warning Status	High Warning Status	Composite Warning Status
Don't Care	TRUE	Don't Care	Don't Care	Flat
Don't Care	False	TRUE	Don't Care	Low
Don't Care	False	False	TRUE	High
Transmitter Fau	False	False	False	Fault
In Range	False	False	False	In Range

Table

- [0064] Thus, the composite warning status has an independent flat warning status portion, a high warning status portion, and a low warning status portion. Also, the composite warning may also include a sensor status portion to indicate a transmitter fault on behalf of the pressure sensor. In response to the composite warning status signal, the tire pressure monitoring system may provide some indication through the indicator such as a displayed word, a series of words, an indicator light or a text message that service or adjustment of the tire pressure may be required.

- [0065] Referring now to Figure 14, a method for automatically updating the system when a pressure suddenly increases. In step 220 the tires are associated with the vehicle locations. Various methods for associating the vehicle tire locations are described herein. In step 222 the operator fills the tire and thereby increases the pressure therein. In step 224 the pressure sensor circuit preferably transmits a pressure reading when an increase of a predetermined amount is sensed. In the present

example, 1.5 psi is used. Thus, when the pressure is at least 1.5 psi the system receives a pressure warning from that tire. In step 226 the increased pressure reading is compared to a normal range. If the pressure increase still does not provide a pressure reading within the normal range the warning statuses are maintained in step 228. In step 226 when the new pressure reading is within the normal range the warnings are automatically reset in step 230 for that particular time. The displays and the warning status memory may all be reset.

[0066] In step 232 new warning statuses are generated for each of the rolling locations of the vehicle. Also, a new status may also be generated for a spare tire.

[0067] Referring now to Figure 15, the present invention preferably automatically updates the warning statuses of the system in response to increased tire pressure that indicates replacement of one of the tires with the spare tire. In step 240 each tire is associated with a rolling location in the vehicle. The spare tire is associated with the spare tire location. Various methods for associating as described above may be used. In step 242 the vehicle operator places the spare tire into a rolling position. Preferably, the spare tire is placed in the rolling tire position with a low tire pressure. However, the present invention does not rely upon proper placement. In step 244 the prior spare tire is awakened when rolling movement is provided. The system recognizes that this tire was a previous spare tire and thus now places the spare tire identification into the memory. Thus, the previously spare tire is now associated with a rolling location. When the previously spare tire is associated with a rolling location the warning statuses in the warning status memory are reset in step 246. In step 248 the previous spare may be associated into the non-rolling location in the memory after the warning status is generated or in step 244 as mentioned above. In step 250 new warning statuses are generated for the rolling locations that include the previous spare tire.

[0068] The resetting of the warning statuses in step 246 may include resetting the display on which each of the warning statuses are displayed.

[0069] Referring now to Figure 16, step 240 is illustrated in more detail. The system starts in block 281 when a message expected from a tire is missed by the control system. The missed message may, for example, be from a fourth tire in a four tire

system that has been replaced with another tire such as a spare. The missed message initiates a timer represented by arrow 278. If a message is received before a predetermined time, and the tire is a rolling tire and the timer is stopped as represented by arrow 280. When the timer expires and the vehicle speed is indicative of the vehicle moving in block 281, the tire status is set to a pending spare as represented by block 282. If the vehicle stops moving the tire status is again set to rolling.

[0070] Referring back to block 282, when the status is a pending spare status and any of the other tires have a pending rolling status block 284 is executed in which the tire status is set as a spare status. When the tire status is set to spare and a pressure message is received and the vehicle is moving, a counter is initiated and a timer is started as illustrated by arrow 286. If the timer expires, the count is set to zero as represented by arrow 288 and the spare tire status is maintained. Likewise, if the vehicle is not moving the counter is reset to zero and the timer is stopped as represented by arrow 290. In this manner the spare tire status is maintained. If the counter counts to a predetermined count indicative of a number of messages received, the tire status is set to pending rolling and the count is reset to zero as represented by block 292. In block 292 if the vehicle stops moving the tire status is once again returned to spare status and the functions described above with respect to block 284 are executed. In block 292, if any of the other tire statuses is a pending spare status, then the tire status is rolling and the system returns to block 281.

[0071] From the above, it is evident that the vehicle speed sensor and a timer are used to distinguish the various statuses of the vehicle. Thus, when an expected transmission is missed, the system recognizes the spare tire and stores the spare tire identification within the system along with the status. Thereafter, the spare tire becomes recognized as one of the rolling tires and thus the system operates receiving normal updates from each of the tires at the rolling positions. As can be seen at least one tire must be in a pending rolling status and one in a pending spare status for the system to change the status. This indicates the movement of one tire. Also, this system presumes that the identification of the spare is known.

[0072] The tire pressure monitoring system 12 of the present invention is preferably



suitable for use with auxiliary tires in auxiliary locations. The auxiliary tires may, for example be positioned on a trailer 300. Trailer 300 is illustrated having a plurality of auxiliary positions including trailer tires 14F, 14G, 14H, and 14I. The trailer may also carry spare tires in auxiliary locations such as tire 14J and 14K. Each of the auxiliary tires includes a respective transmitter 16F-16J and a transmitting antenna 18F-18J. The vehicle itself may also have an auxiliary location such as on top of the roof, underneath the vehicle, or attached to the rear bumper. The present invention senses the presence of an auxiliary tire associated with the vehicle and programs the auxiliary transmitter's identification into the warning status memory. Each of the vehicle transmitters 16F-16J has an associated transmitter identification. The transmitter identifications are programmed into the system so that little chance of erroneous entry is provided.

[0073] Referring now to Figure 18, indicator 52 is illustrated as an LED display 302. LED display 302 has LEDs 304A, 304B, 304C, and 304D corresponding to rolling locations of the vehicle. In addition, an LED 304E corresponding to the position of the spare tire location is shown. In addition, an auxiliary LED 304F is shown. LED 304F corresponds to one or many of the auxiliary locations possible. Of course, those skilled in the art will recognize that several auxiliary LEDs may be incorporated into display 302. An audible indicator 306 may also be incorporated into display 302. Various other forms of display such as a liquid crystal display, navigation system display, or other types of displays may be incorporated into the system.

[0074] Referring now to Figure 19, a method according to the present invention is shown. In step 310 a plurality of transmissions is received from the transmitters around the vehicle. These transmitters may include transmitters that have not yet been programmed into the vehicle warning status memory. It should be noted that the auxiliary sensors as well as other transmissions from adjacent vehicle transmitters may also be received. In step 314, the amount of time of a transmission is also monitored. The amount of time may, for example be the cumulative time or the cumulative time over a monitored period. In step 316 when the vehicle has been in motion for a predetermined amount of time as measured by steps 312 and 314, step 318 is executed. In step 318 if more than five sensors have been received for at least a predetermined amount of time, step 320 is executed. Step 318 used five sensors to

